ESTF2020

Geostationary Satellites and Deep Learning

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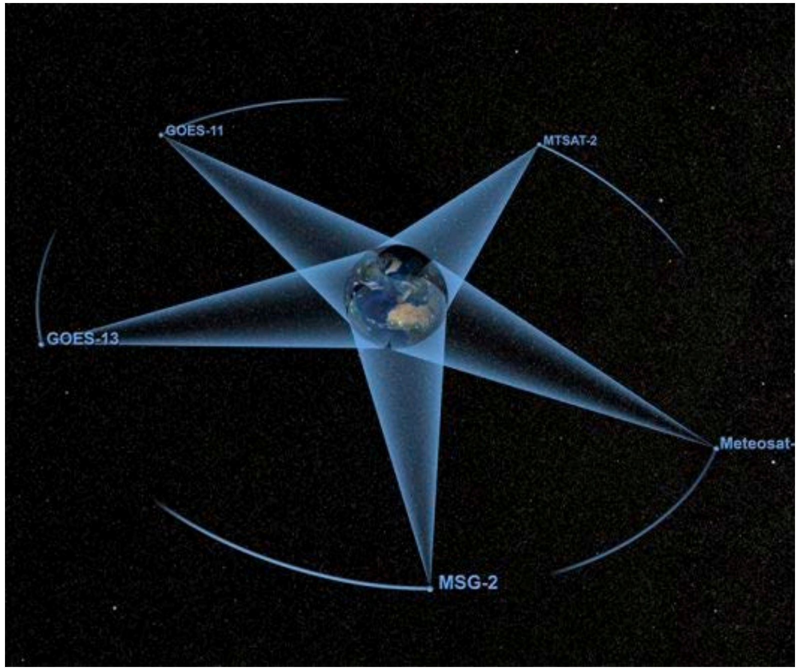
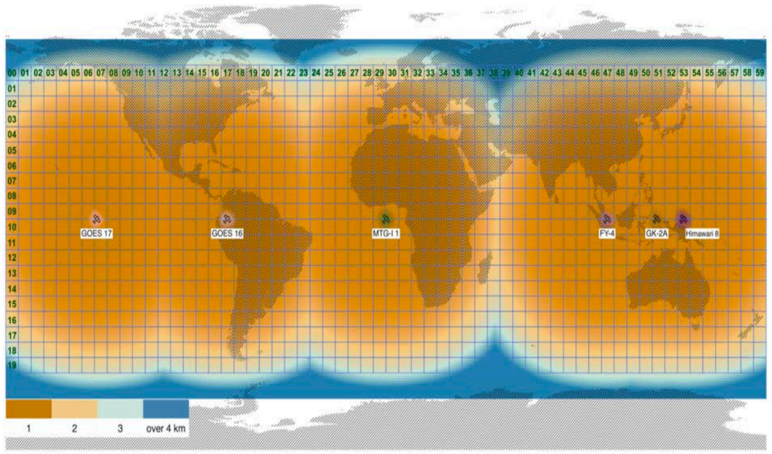
Geostationary Virtual Sensors

- Geostationary (GEO) satellite sensors are used to monitor the atmosphere, land, and oceans in high-frequency intervals
- Imagery from multiple GEO sensors allows for near constant monitoring of large regions
- Current sensors flying on GOES-16/17 (NOAA /NASA), Himawari-8 (Japan), GEO-KOMSAT-2A (South Korea)
- Generates large amounts of data requiring efficient processing
- **Varying spectral coverage** creates inconsistencies between images
- Current models for downstream products cannot be applied across sensors without significant model updates

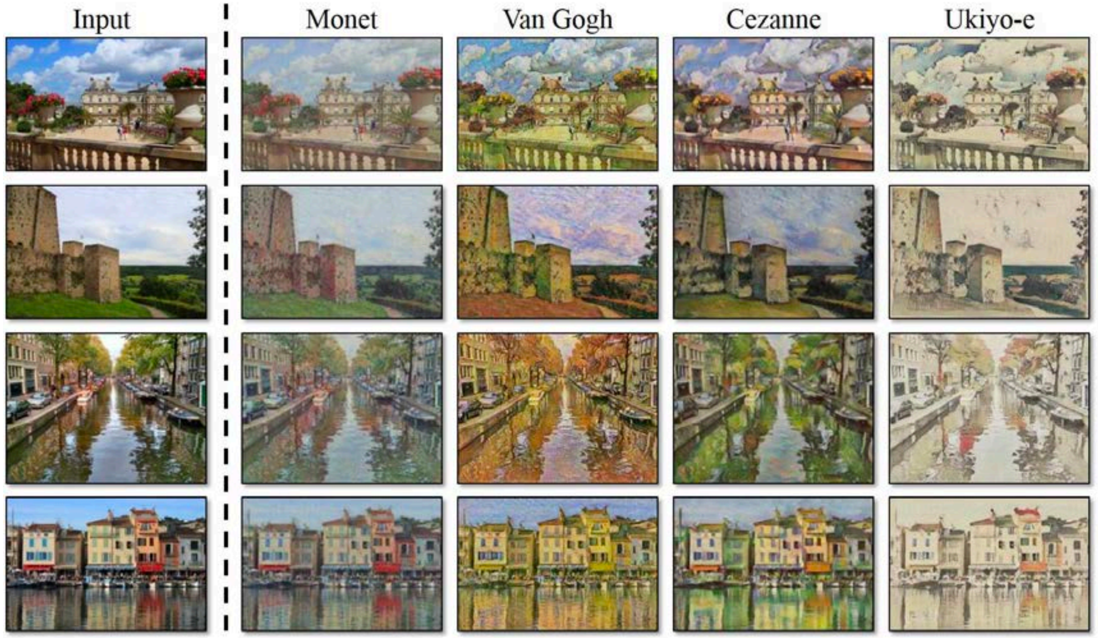




Deep Learning for Image Translation

Image-to-image translation with deep learning has had tremendous success in generating realistic looking images

Tasks include: Image-colorization, style transfer, super-resolution, etc.

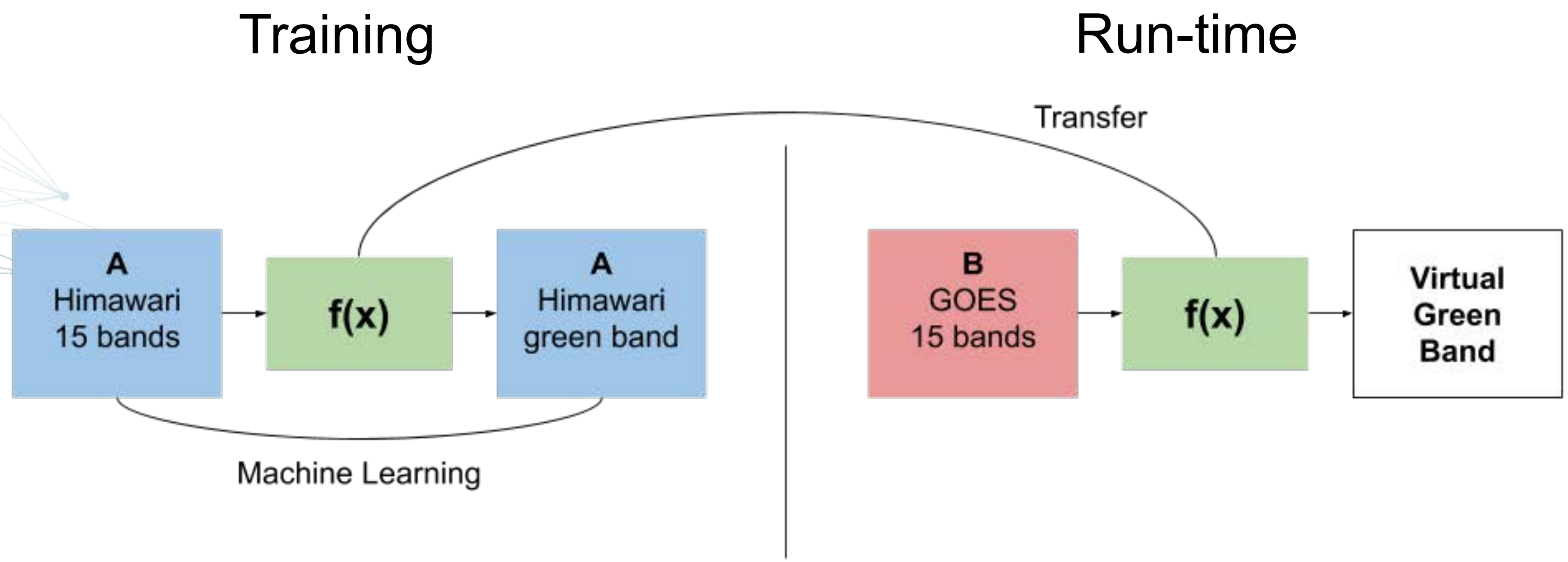


Applications to remote sensing: Cross satellite synchronization with virtual sensors, land and cloud segmentation, image denoising, and compression

Virtual Sensing - Supervised

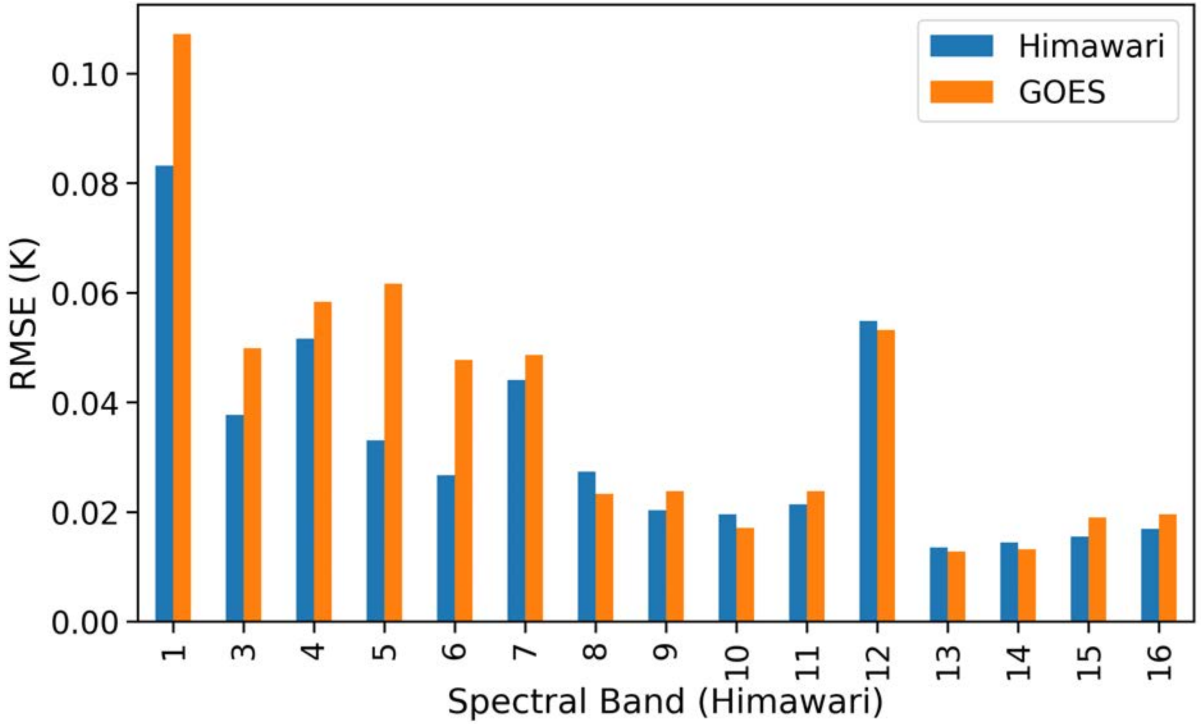
Given two satellites **A** and **B** with spectral bands, **A**=$\{\alpha_1, \alpha_{2,\dots,}\alpha_K\}$ and **B**=$\{\beta_1, \beta_{2,\dots,}\beta_K\}$ then **S** = **A** ∩ **B**.

Let, y to be some α_i not in **S**, then a function y ≅ f(**S**) can be learned from **A** to **B**.

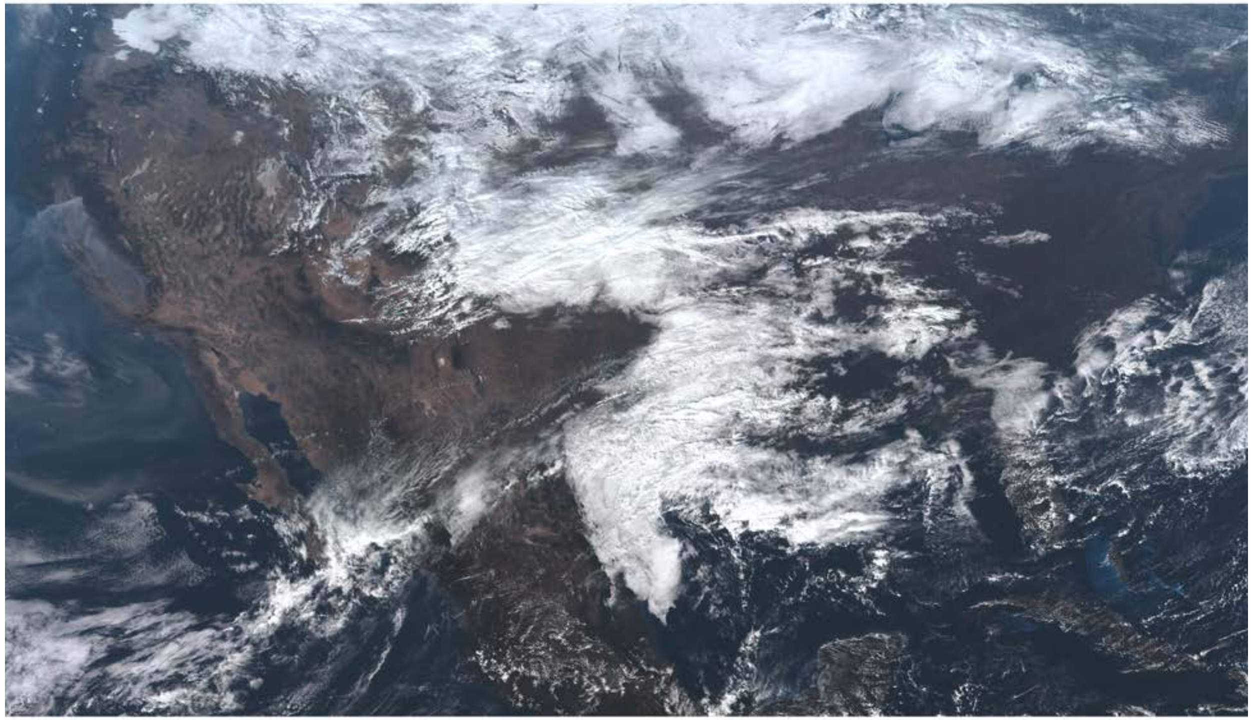


Results - GOES-16 and Himawari-8

Cross-validation Dropping Bands



GOES-16 True Color Image with virtual green band

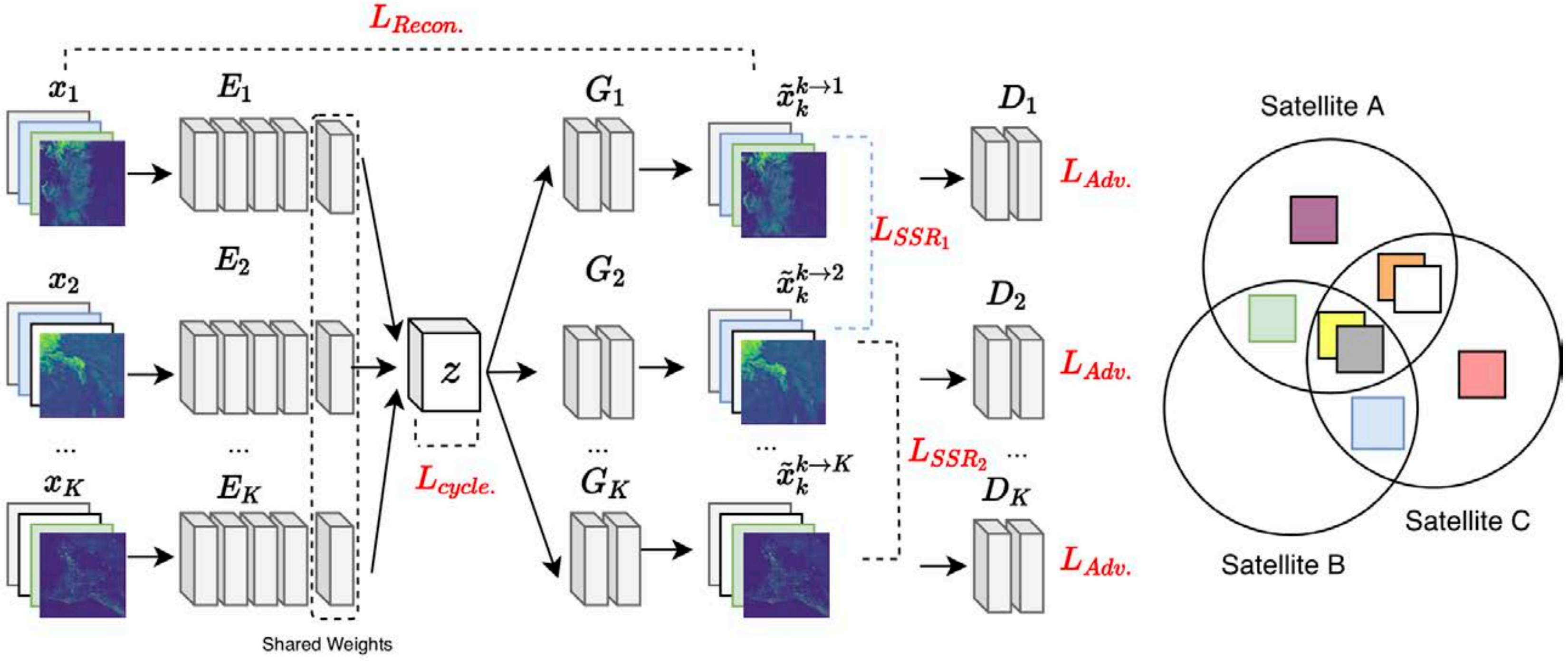


Virtual Sensing - Unsupervised

Paired images across sensors are often unavailable or limited but **large independent datastores are available**

Unsupervised Learning removes the dependence on labels and learns only from the inputs

Unsupervised Spectral Synthesis across geostationary satellites with a Variational Autoencoder and Generate Adversarial Network Architecture (Vandal 2020)



Downstream Cloud Detection (Unsupervised)

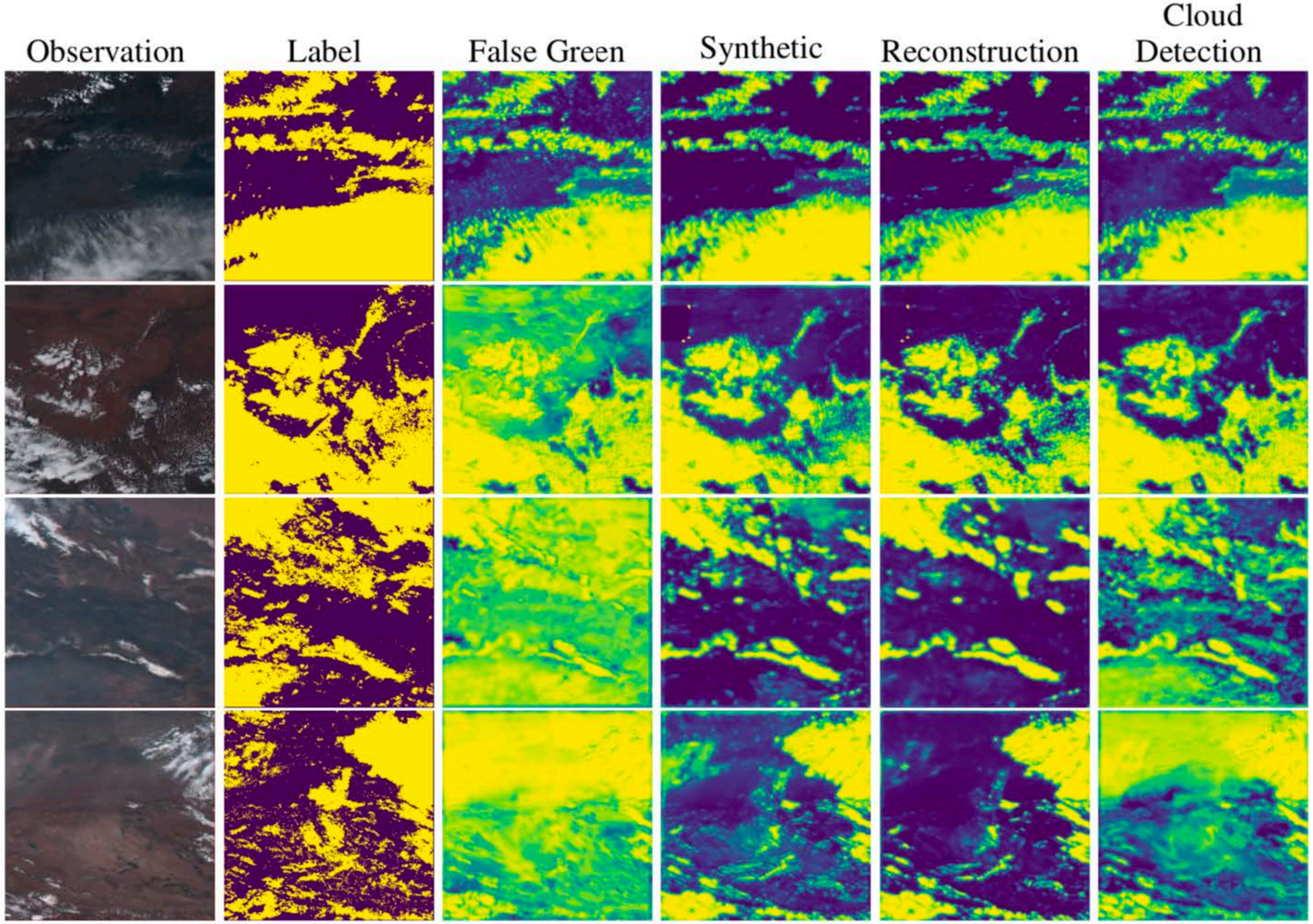
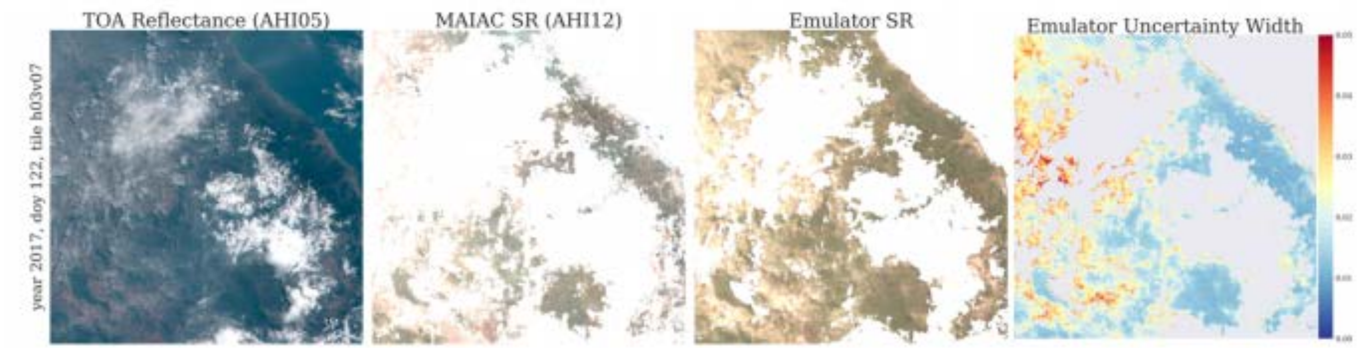


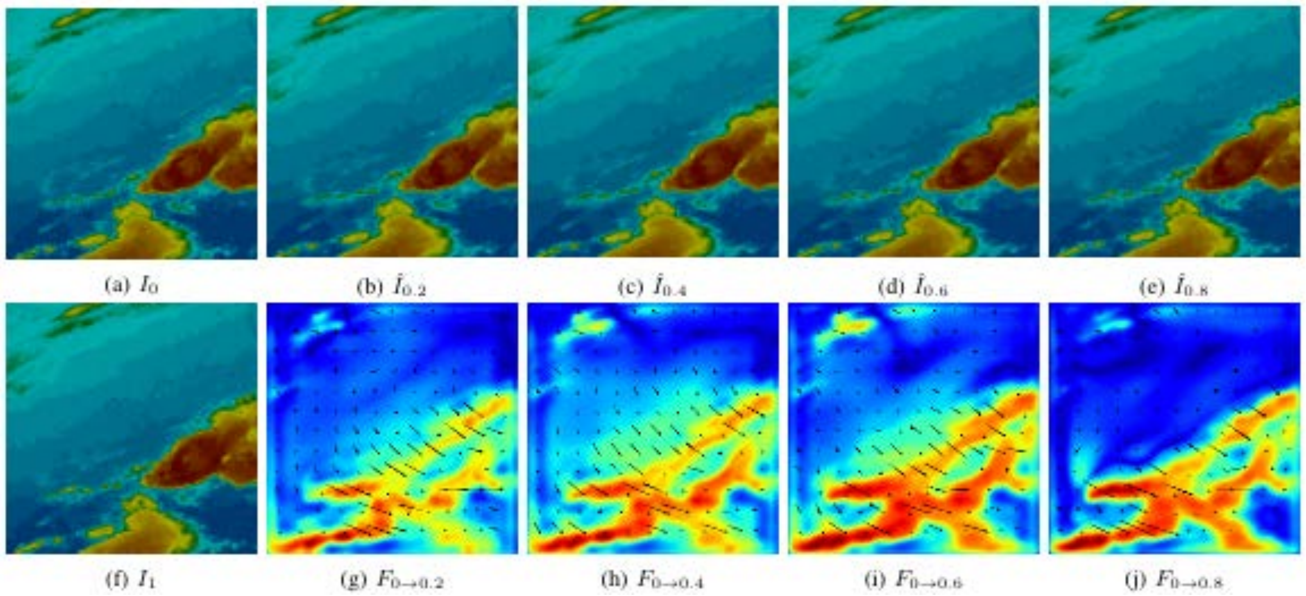
Figure 5: Cloud segmentation of four Himawari-8 observations. From left to right, columns show observation and cloud mask labels followed by false color, synthesized, reconstructed, and observed segmentation. Yellow denotes cloud pixels and blue non-cloudy pixels.

Related Applications

Emulation of computationally expensive physical models (Duffy 2019)



Atmospheric motion and temporal interpolation using optical flow (Vandal 2020)



Pros and Cons

Supervised Virtual Sensing

++ Produces fast and accurate approximations

++ Epistemic and aleatoric uncertainties captured

-- Paired images are often unavailable for training

-- Current approach uses Monte Carlo sampling at inference

Unsupervised Virtual Sensing

++ Unpaired datasets are widely available

++ Learns more generalizable and consistent models

-- Optimization function is not well suited to high-resolution images

-- Increased model complexity and computational requirements

Conclusions

Introduced supervised and unsupervised approaches to image-to-image translation tasks in remote sensing

Virtual sensors with deep learning can generate accurate estimates of synthetic bands in the supervised scenario

Unsupervised image-to-image translation is a promising approach to extend beyond paired datasets

Next steps

Extend applications of image-to-image translation to super-resolution, video processing, and segmentation tasks on remote sensing data.

Improve accuracies in unsupervised learning to compete with supervised models.

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References

1. Vandal, T. & Nemani, R. (2019). "Optical Flow for Intermediate Frame Interpolation of Multispectral Geostationary Satellite Data". Arxiv. (In review)
2. Duffy, K., Vandal, T., Wang, W., Nemani, R., & Ganguly, A. R. (2019). Deep Learning Emulation of Multi-Angle Implementation of Atmospheric Correction (MAIAC). arXiv preprint arXiv:1910.13408. Arxiv. (In review)
3. Vandal, T., McDuff, D., Wang, W., Michaelis, A., & Nemani, R. (2020). "Unsupervised Spectral Synthesis for Satellite-to-Satellite Translation." (In review, NeurIPS)
4. Gao, N., Wilson, M., Vandal, T., Vinci, W., Nemani, R., & Rieffel, E. "High-Dimensional Similarity Search with Quantum-Assisted Variational Autoencoder," Proceedings of the 26th ACM SIGKDD Conference on Knowledge Discovery and Data Mining (Research Track, 16% acceptance rate).